

APPENDIX V

UNIFIED SOIL CLASSIFICATION SYSTEM

The figure and tables in appendix V relate to identification and classification of soil.

Table AV-1 presents useful information concerning the Unified Soil Classification System.

Figure AV- 1 concerns the classification of soil after the soil has been visually identified as coarse grained, fine grained, or highly organic.

Table AV-2 shows soil characteristics pertinent to roads and airfields.

Table AV-3 shows soil characteristics pertinent to embankments and foundations.

Table AV-1.— Unified Soil Classification System.

UNIFIED SOIL CLASSIFICATION (Including Identification and Description)									
Major Divisions		Group Symbols	Typical Names		Field Identification Procedures (Excluding particles larger than 3 in. and basing fractions on estimated weights.)				
1	2	3	4		5				
Coarse-grained Soils More than half of material is larger than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Gravels More than half of coarse fraction is larger than No. 4 sieve size (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean Gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.				
			GP	Poorly graded gravels or gravel-sand mixtures, little or no fines.	Predominantly one size or a range of sizes with some intermediate sizes missing.				
		Gravels with Fines (Appreciable amount of fines)	GM	Silty gravels, gravel-sand-silt mixture.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below.)				
			GC	Clayey gravels, gravel-sand-clay mixtures.	Plastic fines (for identification procedures see CL below.)				
	Sands More than half of coarse fraction is smaller than No. 4 sieve size (For visual classification, the 1/4-in. size may be used as equivalent to the No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines	Wide range in grain size and substantial amounts of all intermediate particle sizes.				
			SP	Poorly graded sands or gravelly sands, little or no fines	Predominantly one size or a range of sizes with some intermediate sizes missing.				
		Sands with Fines (Appreciable amount of fines)	SM	Silty sands, sand-silt mixtures.	Nonplastic fines or fines with low plasticity (for identification procedures see ML below.)				
			SC	Clayey sands, sand-clay mixtures.	Plastic fines (for identification procedures see CL below.)				
	Fine-grained Soils More than half of material is smaller than No. 200 sieve size. The No. 200 sieve size is about the smallest particle visible to the naked eye.	Sils and Clays Liquid limit is less than 50			Identification Procedures on Fraction Smaller than No. 40 Sieve Size				
						Dry Strength (Crushing characteristics)	Dilatancy (Reaction to shaking)	Toughness (Consistency near PL)	
ML					Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	None to slight	Quick to slow	None	
Sils and Clays Liquid limit is greater than 50					CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Medium to high	None to very slow	Medium
					OL	Organic silts and organic silts clays of low plasticity.	Slight to Medium	Slow	Slight
					MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Slight to medium	Slow to none	Slight to medium
					CH	Inorganic clays of high plasticity, fat clays	High to very high	None	High
					OH	Organic clays of medium to high plasticity, organic silts.	Medium to high	None to very slow	Slight to medium
Highly Organic Soils		Pe	Peat and other highly organic soils.		Readily identified by color, odor, spongy feel and frequently by fibrous texture.				

- (1) Boundary classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For examples GW-GC, well-graded gravel-sand mixture with clay binder.
- (2) All sieve sizes on this chart are U.S. standard.

FIELD IDENTIFICATION PROCEDURES FOR FINE-GRAINED SOILS OR FRACTIONS

These procedures are to be performed on the minus No. 40 sieve size particles, approximately 1/64 in. For field classification purposes, screening is not intended, simply remove by hand the coarse particles that interfere with the tests.

Dry Strength (crushing characteristics)

After removing particles larger than No. 40 sieve size, mold a pat of soil to the consistency of putty, adding water if necessary. Allow the pat to dry completely by oven, sun, or air-drying, and then test its strength by breaking and crumbling between the fingers. This strength is a measure of the character and quantity of the colloidal fraction contained in the soil. The dry strength increases with increasing plasticity.

High dry strength is characteristic for clays of the CH group. A typical inorganic silt passes only very slight dry strength. Silty fine sands and silts have about the same slight dry strength, but can be distinguished by the feel when powdering the dried specimen. Fine sand feels gritty whereas a typical silt has the smooth feel of flour.

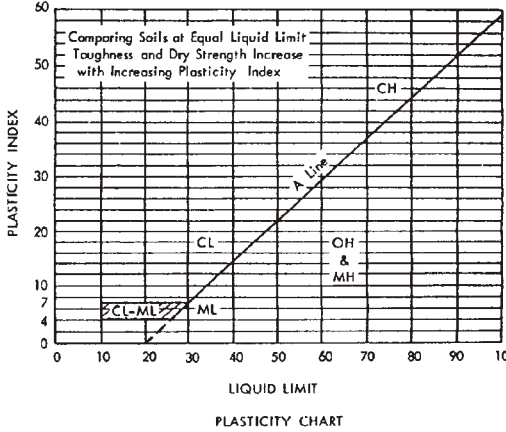
Dilatancy (reaction to shaking)

After removing particles larger than No. 40 sieve size, prepare a pat of moist soil with a volume of about one-half cubic inch. Add enough water if necessary to make the soil soft but not sticky.

Place the pat in the open palm of one hand and shake horizontally, striking vigorously against the other hand several times. A positive reaction consists of the appearance of water on the surface of the pat which changes to a livery consistency and becomes glossy. When the sample is squeezed between the fingers, the water and gloss disappear from the surface, the pat stiffens, and finally it cracks or crumbles. The rapidity of appearance of water during shaking and of its disappearance during squeezing assist in identifying the character of the fines in a soil.

Very fine clean sands give the quickest and most distinct reaction whereas a plastic clay has no reaction. Inorganic silts, such as a typical rock flour, show a moderately quick reaction.

Table AV-1.— Unified Soil Classification System— Continued.

UNIFIED SOIL CLASSIFICATION (Including Identification and Description)						
Information Required for Describing Soil	Laboratory Classification Criteria					
6	7					
<p>For undisturbed soils add information on stratification, degree of compactness, cementation, moisture conditions, and drainage characteristics.</p> <p>Give typical name; indicate approximate percentage of sand and gravel, maximum size; angularity, surface condition, and hardness of the coarse grains; local or geologic name and other pertinent descriptive information; and symbol in parentheses.</p> <p>Example: Silty sand, gravelly; about 20% hard, angular or gravel particles 1/2-in. maximum size; rounded and subangular sand grains, coarse to fine; about 15% nonplastic fines with low dry strength; well compacted and moist in place; alluvial sand; (SM).</p>	<p>Determine percentages of gravel and sand from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size) coarse-grained soils are classified as follows:</p> <p>GW, GP, SW, SP, GM, GC, SM, SC. Borderline cases requiring use of dual symbols.</p> <p>Less than 5% More than 12% 5% to 12%</p>	$C_u = \frac{D_{60}}{D_{10}} \text{ Greater than 4}$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} \text{ Between 1 and 3}$ <p>Not meeting all gradation requirements for GW</p> <table border="1"> <tr> <td>Atterberg limits below "A" line or PI less than 4</td> <td>Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.</td> </tr> <tr> <td>Atterberg limits above "A" line with PI greater than 7</td> <td></td> </tr> </table>	Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.	Atterberg limits above "A" line with PI greater than 7	
Atterberg limits below "A" line or PI less than 4	Above "A" line with PI between 4 and 7 are borderline cases requiring use of dual symbols.					
Atterberg limits above "A" line with PI greater than 7						
		$C_u = \frac{D_{60}}{D_{10}} \text{ Greater than 6}$ $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}} \text{ Between 1 and 3}$ <p>Not meeting all gradation requirements for SW</p> <table border="1"> <tr> <td>Atterberg limits below "A" line or PI less than 4</td> <td>Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.</td> </tr> <tr> <td>Atterberg limits above "A" line with PI greater than 7</td> <td></td> </tr> </table>	Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.	Atterberg limits above "A" line with PI greater than 7	
Atterberg limits below "A" line or PI less than 4	Limits plotting in hatched zone with PI between 4 and 7 are borderline cases requiring use of dual symbols.					
Atterberg limits above "A" line with PI greater than 7						
<p>For undisturbed soils add information on structure stratification, consistency in undisturbed and remolded states, moisture and drainage conditions.</p> <p>Give typical name; indicate degree and character of plasticity; amount and maximum size of coarse grains; color in wet condition; odor, if any; local or geologic name and other pertinent descriptive information; and symbol in parentheses.</p> <p>Example: Clayey silt, brown; slightly plastic; small percentage of fine sand; numerous vertical root holes; firm and dry in place; loess; (ML).</p>	<p>Use grain-size curve in identifying the fractions at given under field identification.</p>  <p>For laboratory classification of fine-grained soils</p>					

Toughness (consistency near plastic limit)

After particles larger than the No. 40 sieve size are removed, a specimen of soil about one-half inch in cube size, is molded to the consistency of putty. If too dry, water must be added and if sticky, the specimen should be spread out in a thin layer and allowed to lose some moisture by evaporation. Then the specimen is rolled out by hand on a smooth surface or between the palms into a thread about one-eighth inch in diameter. The thread is then folded and rerolled repeatedly. During this manipulation the moisture content is gradually reduced and the specimen stiffens, finally loses its plasticity, and crumbles when the plastic limit is reached.

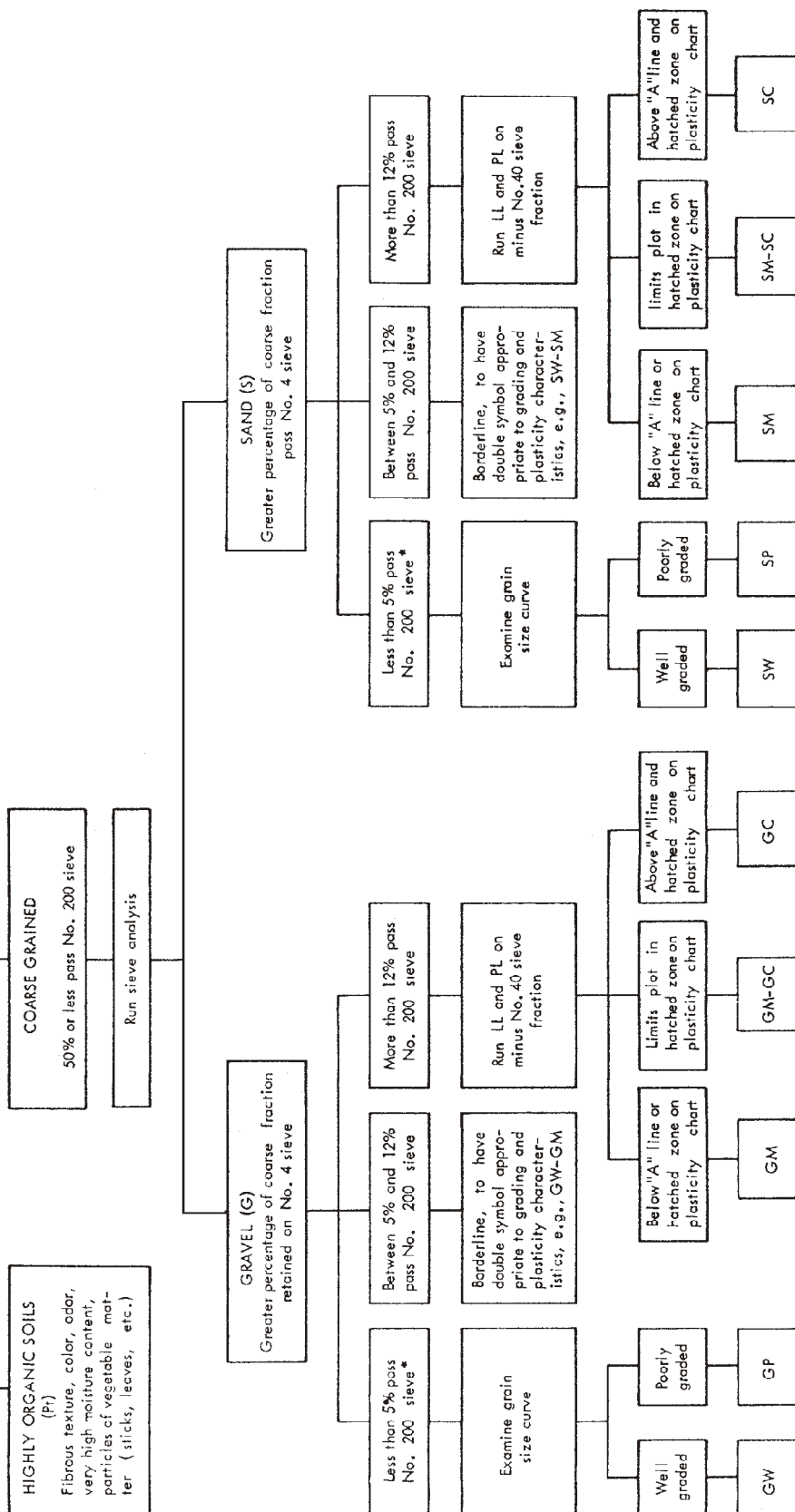
After the thread crumbles, the pieces should be lumped together and a slight kneading action continued until the lump crumbles.

The tougher the thread near the plastic limit and the stiffer the lump when it finally crumbles, the more potent is the colloidal clay fraction in the soil.

Weakness of the thread at the plastic limit and quick loss of coherence of the lump below the plastic limit indicate either inorganic clay of low plasticity, or materials such as kaolin-type clays and organic clays which occur below the A-line. Highly organic clays have a very weak and spongy feel at the plastic limit.

Make visual examination of soil to determine whether it is HIGHLY ORGANIC, COARSE GRAINED, OR FINE GRAINED. In borderline cases determine amount passing No. 200 sieve.

Continued on next page



Note: Sieve sizes are U.S. Standard.

Figure AV-1.—Identification of soils.

Make visual examination of soil to determine whether it is HIGHLY ORGANIC, COARSE GRAINED, OR FINE GRAINED. In borderline cases determine amount passing No. 200 sieve.

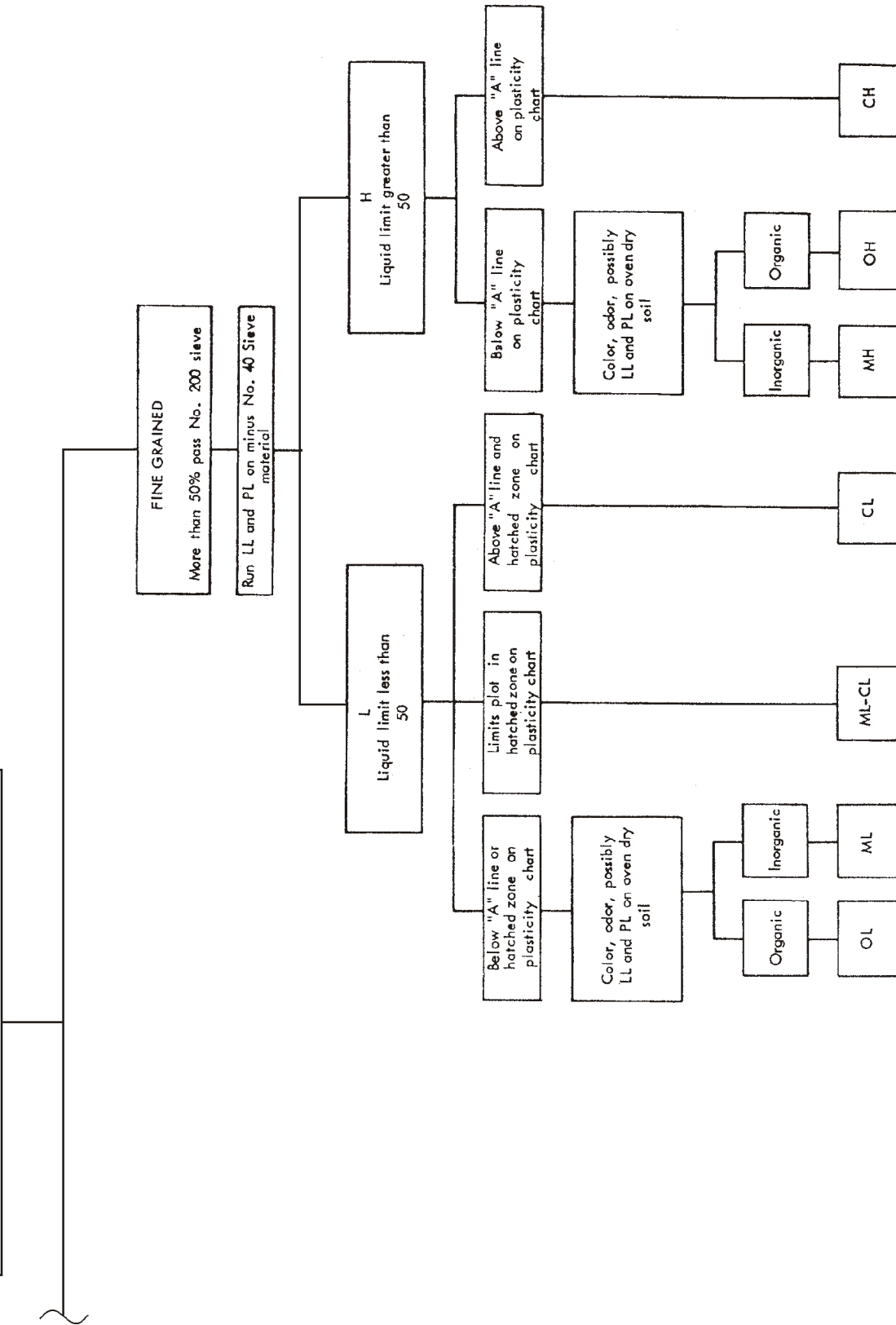


Figure AV-1.— Identification of soils — Continued.

Table AV-2.— Soil Classification Pertinent to Roads and Airfields.

Major Divisions (1) (2)		Letter (3)	Symbol		Name (6)	Value as Foundation When Not Subject to Frost Action (7)	Value as Base Di- rectly under Bi- tuminous Pavement (8)	
			Hatching (4)	Color (5)				
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Excellent	Good	
		GP			Poorly graded gravels or gravel-sand mixtures, little or no fines	Good to excellent	Poor to fair	
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Good to excellent	Fair to good	
					Good	Poor		
		GC		Clayey gravels, gravel-sand-clay mixtures	Good	Poor		
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Good	Poor	
		SP			Poorly graded sands or gravelly sands, little or no fines	Fair to good	Poor to not suitable	
		SM		Yellow	Silty sands, sand-silt mixtures	Good	Poor	
					Fair to good	Not suitable		
		SC		Clayey sands, sand-clay mixtures	Fair to good	Not suitable		
	FINE GRAINED SOILS	SILTS AND CLAYS LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Fair to poor	Not suitable
			CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Fair to poor	Not suitable
			OL			Organic silts and organic silt-clays of low plasticity	Poor	Not suitable
		SILTS AND CLAYS LL > 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor	Not suitable
CH				Inorganic clays of high plasticity, fat clays		Poor to very poor	Not suitable	
OH				Organic clays of medium to high plasticity, organic silts		Poor to very poor	Not suitable	
HIGHLY ORGANIC SOILS		Pt		Orange	Peat and other highly organic soils	Not suitable	Not suitable	

Notes:

- Column 3, Division of GM and SM groups into subdivisions of d and u are for roads and airfields only; subdivision is on basis of Atterberg limits; suffix d (e. g., GMd) will be used when the liquid limit is 26 or less and the plasticity index is 6 or less; the suffix u will be used when the liquid limit is greater than 26.
- Column 7, values are for subgrades and base courses except for base course directly under bituminous pavement.
- In column 8, the term "excellent" has been reserved for base materials consisting of high quality processed crushed stone.
- In column 9, these soils are susceptible to frost as indicated under conditions favorable to frost action described in the text.
- In column 12, the equipment listed will usually produce the required densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled. In some instances, several types of equipment are listed, because variable soil characteristics within a given soil group may require different equipment. In some instances, a combination of two types may be necessary.
 - Processed base materials and other angular materials. Steel-wheeled rollers are recommended for hard angular materials with limited fines or screenings. Rubber-tired equipment is recommended for softer materials subject to degradation.
 - Finishing. Rubber-tired equipment is recommended for rolling during final shaping operations for most soils and processed materials.
 - Equipment size. The following sizes of equipment are necessary to assure the high densities required for airfield construction:
 - Crawler-type tractor -- total weight in excess of 30,000 lb.
 - Rubber-tired equipment -- wheel load in excess of 15,000 lb, wheel loads as high as 40,000 lb may be necessary to obtain the required densities for some materials (based on contact pressure of approximately 65 to 150 psi).
 - Sheepsfoot roller -- unit pressure (on 6- to 12-sq-in. foot) to be in excess of 250 psi and unit pressures as high as 650 psi may be necessary to obtain the required densities for some materials. The area of the feet should be at least 5 per cent of the total peripheral area of the drum, using the diameter measured to the faces of the feet.
- Column 13, unit dry weights are for compacted soil at optimum moisture content for modified AASHTO compactive effort.

Table AV-2. — Soil Classification Pertinent to Roads and Airfields — Continued.

Potential Frost Action (9)	Compressibility and Expansion (10)	Drainage Characteristics (11)	Compaction Equipment (12)	Unit Dry Weight Lb Per Cu Ft (13)	Field CBR (14)	Subgrade Modulus k _s Lb Per Cu In. (15)
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment, steel-wheeled roller	125-140	60-80	300 or more
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment, steel-wheeled roller	110-130	25-60	300 or more
Slight to medium	Very slight	Fair to poor	Rubber-tired equipment, sheepsfoot roller; close control of moisture	130-145	40-80	300 or more
Slight to medium	Slight	Poor to practically impervious	Rubber-tired equipment, sheepsfoot roller	120-140	20-40	200 to 300
Slight to medium	Slight	Poor to practically impervious	Rubber-tired equipment, sheepsfoot roller	120-140	20-40	200 to 300
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment	110-130	20-40	200 to 300
None to very slight	Almost none	Excellent	Crawler-type tractor, rubber-tired equipment	100-120	10-25	200 to 300
Slight to high	Very slight	Fair to poor	Rubber-tired equipment, sheepsfoot roller; close control of moisture	120-135	20-40	200 to 300
Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired equipment, sheepsfoot roller	105-130	10-20	200 to 300
Slight to high	Slight to medium	Poor to practically impervious	Rubber-tired equipment, sheepsfoot roller	105-130	10-20	200 to 300
Medium to very high	Slight to medium	Fair to poor	Rubber-tired equipment, sheepsfoot roller; close control of moisture	100-125	5-15	100 to 200
Medium to high	Medium	Practically impervious	Rubber-tired equipment, sheepsfoot roller	100-125	5-15	100 to 200
Medium to high	Medium to high	Poor	Rubber-tired equipment, sheepsfoot roller	90-105	4-8	100 to 200
Medium to very high	High	Fair to poor	Sheepsfoot roller	80-100	4-8	100 to 200
Medium	High	Practically impervious	Sheepsfoot roller	90-110	3-5	50 to 100
Medium	High	Practically impervious	Sheepsfoot roller	80-105	3-5	50 to 100
Slight	Very high	Fair to poor	Compaction not practical	-	-	-

Table AV-3.— Soil Classification Pertinent to Embankments and Foundations.

Major Divisions (1) (2)		Letter (3)	Symbol		Name (6)	Value for Embankments (7)
			Hatching (4)	Color (5)		
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW		Red	Well-graded gravels or gravel-sand mixtures, little or no fines	Very stable, pervious shells of dikes and dams
		GP			Poorly-graded gravels or gravel-sand mixtures, little or no fines	Reasonably stable, pervious shells of dikes and dams
		GM		Yellow	Silty gravels, gravel-sand-silt mixtures	Reasonably stable, not particularly suited to shells, but may be used for impervious cores or blankets
		GC			Clayey gravels, gravel-sand-clay mixtures	Fairly stable, may be used for impervious core
	SAND AND SANDY SOILS	SW		Red	Well-graded sands or gravelly sands, little or no fines	Very stable, pervious sections, slope protection required
		SP			Poorly-graded sands or gravelly sands, little or no fines	Reasonably stable, may be used in dike section with flat slopes
		SM		Yellow	Silty sands, sand-silt mixtures	Fairly stable, not particularly suited to shells, but may be used for impervious cores or dikes
		SC			Clayey sands, sand-silt mixtures	Fairly stable, use for impervious core for flood control structures
FINE GRAINED SOILS	SILTS AND CLAYS LL < 50	ML		Green	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Poor stability, may be used for embankments with proper control
		CL			Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	Stable, impervious cores and blankets
		OL			Organic silts and organic silt-clays of low plasticity	Not suitable for embankments
	SILTS AND CLAYS LL > 50	MH		Blue	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts	Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction
		CH			Inorganic clays of high plasticity, fat clays	Fair stability with flat slopes, thin cores, blankets and dike sections
		OH			Organic clays of medium to high plasticity, organic silts	Not suitable for embankments
HIGHLY ORGANIC SOILS		Pt		Orange	Peat and other highly organic soils	Not used for construction

- Notes: 1. Values in columns 7 and 11 are for guidance only. Design should be based on test results.
2. In column 9, the equipment listed will usually produce the desired densities with a reasonable number of passes when moisture conditions and thickness of lift are properly controlled.
3. Column 10, unit dry weights are for compacted soil at optimum moisture content for Standard AASHO (Standard Proctor) compactive effort.

TableAV-3.— Soil Classification Pertinent to Embankments and Foundations — Continued.

Permeability Cm Per Sec (8)	Compaction Characteristics (9)	Std AASHTO Max Unit Dry Weight Lb Per Cu Ft (10)	Value for Foundations (11)	Requirements for Seepage Control (12)
$k > 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	125-135	Good bearing value	Positive cutoff
$k > 10^{-2}$	Good, tractor, rubber-tired, steel-wheeled roller	115-125	Good bearing value	Positive cutoff
$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	120-135	Good bearing value	Toe trench to none
$k = 10^{-6}$ to 10^{-8}	Fair, rubber-tired, sheepsfoot roller	115-130	Good bearing value	None
$k > 10^{-3}$	Good, tractor	110-130	Good bearing value	Upstream blanket and toe drainage or wells
$k > 10^{-3}$	Good, tractor	100-120	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
$k = 10^{-3}$ to 10^{-6}	Good, with close control, rubber-tired, sheepsfoot roller	110-125	Good to poor bearing value depending on density	Upstream blanket and toe drainage or wells
$k = 10^{-6}$ to 10^{-8}	Fair, sheepsfoot roller, rubber tired	105-125	Good to poor bearing value	None
$k = 10^{-3}$ to 10^{-6}	Good to poor, close control essential, rubber-tired roller, sheepsfoot roller	95-120	Very poor, suscepti- ble to liquefaction	Toe trench to none
$k = 10^{-6}$ to 10^{-8}	Fair to good, sheepsfoot roller, rubber tired	95-120	Good to poor bearing	None
$k = 10^{-4}$ to 10^{-6}	Fair to poor, sheepsfoot roller	80-100	Fair to poor bearing, may have excessive settlements	None
$k = 10^{-4}$ to 10^{-6}	Poor to very poor, sheepsfoot roller	70-95	Poor bearing	None
$k = 10^{-6}$ to 10^{-8}	Fair to poor, sheepsfoot roller	75-105	Fair to poor bearing	None
$k = 10^{-6}$ to 10^{-8}	Poor to very poor, sheepsfoot roller	65-100	Very poor bearing	None
Not used for construction	Compaction not practical		Remove from foundations	

